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THE CONTROL OF TOMATO LEAF-SPOT

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INTRODUCTION

Leaf-spot, or blight (*Septoria lycopersici* Speg.; Pl. I, *A* to *C*), of tomato plants causes an average annual loss of approximately 250,000 tons of tomatoes in the United States.[1] In addition to this loss in yield it also causes considerable reduction in quality of fruit. Because of the defoliation of the plants the fruits do not mature properly, but remain small, yellow, watery, and deficient in solids and flavoring materials. As they have no protection from the sun by the leaves, many of them also become sun scalded (figs. 1 and 2). Such fruits are therefore deficient in color and food value and unsuitable for making a first-class manufactured product.

Leaf-spot is widely distributed east of the Rocky Mountains and is commonly destructive in those parts of the Middle Atlantic and Middle Western States that lie in a temperature belt of 73° to 78° F. during the growing season, but owing to the parasite's narrow range of sporulation temperatures, viz, 59° to 80.5° F. (*12*),[2] this disease is relatively unimportant in States farther north and south and is absent in the Pacific coast region (figs. 3 and 4). It thrives best in a humid atmosphere and therefore is more abundant in Maryland,

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[1] This is exclusive of losses in home gardens and truck patches grown for local markets.

[2] Serial numbers (*italic*) in parentheses refer to "Literature cited," at the end of this bulletin.

Virginia, and the adjoining coast States than in inland parts of the same temperature belt.

NATURAL METHODS OF OVERWINTERING

The tomato leaf-spot fungus (*Septoria lycopersici*) lives over winter on dead tomato vines and leaves lying on the surface of the ground. During the fall and spring it multiplies in the epidermal and subepidermal tissues of these stems and leaves and in summer produces numerous fruiting bodies (pycnidia) and spores. The fresh spores are carried by insects and other agents to young tomato plants, which become infected and serve as starting points for the seasonal distribution of the disease.

As the tomato leaf-spot fungus infects a number of other hosts, it is doubtless capable of living over winter on them in much the same way as on tomato vines. Aside from the tomato its most common hosts in the Middle Atlantic and Middle Western States are probably horsenettle (*Solanum carolinense*) and jimsonweed (*Datura stramonium*). It not only infects these hosts readily but produces spores on them. *Datura tatula* was listed as a host of this fungus by Norton (*5*) but the writers have found that it infects *D. stramonium* quite as readily. Since Safford (*13*, *14*) has shown that *D. tatula* is in reality only a form of *D. stramonium* instead of a distinct species, this is not surprising. *D. tatula* differs from *D. stramonium* by having purple stems and violet flowers instead of green stems and white flowers. Safford found that both violet and white flowered forms come from seed of the same *D. tatula* plant, and the writers have since obtained similar results.

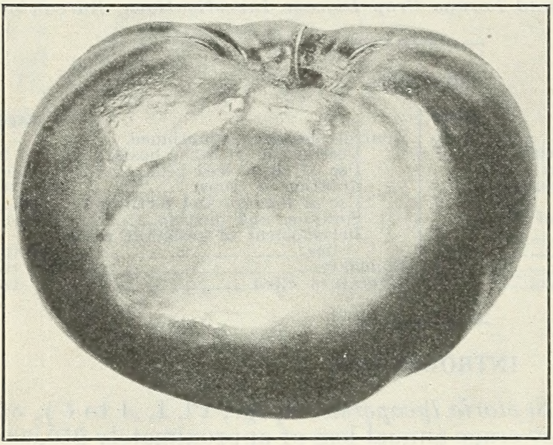


FIG. 1.—Sun scald of tomato fruit. This commonly is found on the side of the fruit facing the sun after the plants are defoliated by leaf-spot

POSSIBILITIES OF OVERWINTERING ON DEAD WEEDS, GRASSES, AND REMAINS OF VARIOUS CROPS

There is a paucity of information on the growth and overwintering of parasitic fungi on dead material other than that of the host. Much stress is often laid on the destruction of living wild host plants, but little attention is given to the possibility that the parasites may live and multiply on dead organic matter of various kinds. Many dead weeds and pieces of crop plants frequently lie on the surface of the ground where they are not subject to the chemical effects of the soil and yet are kept favorably moist. To what extent parasites grow and sporulate on such materials is not known.

The writers carried on some experiments with Septoria and a number of other tomato parasites to determine whether they will grow and live over winter on dead weeds, grasses, and other plants. The results reported in this bulletin are on *Septoria lycopersici.* Stems of cotton (*Gossypium herbaceum*) and of sweet clover (*Melilotus officinalis*) and pieces of crabgrass (*Syntherisma sanguinalis*), mixed field grasses (chiefly *Agrostis alba*, *Phleum pratense*, *Dactylis glomerata*, and *Poa pratensis*), cornstalks (*Zea mays*), ragweed (*Ambrosia artemisiaefolia*), rough pigweed (*Amaranthus retroflexus*), lambs-quarters (*Chenopodium album*), and *Eleusine indica* were placed in glass tubes, sterilized, and inoculated with a pure culture of *Septoria lycopersici.* After the cultures were kept in the laboratory 18 to 21 days to give them a start, they were placed in gallon cans closed with rubber corks and ventilated by means of curved glass tubing plugged with cotton wool. These cans were packed in rows in an open coldframe exposed to outdoor temperatures during the winter. The following spring and summer the cultures were removed from the cans and repeatedly examined. The results are summarized in Table 1.

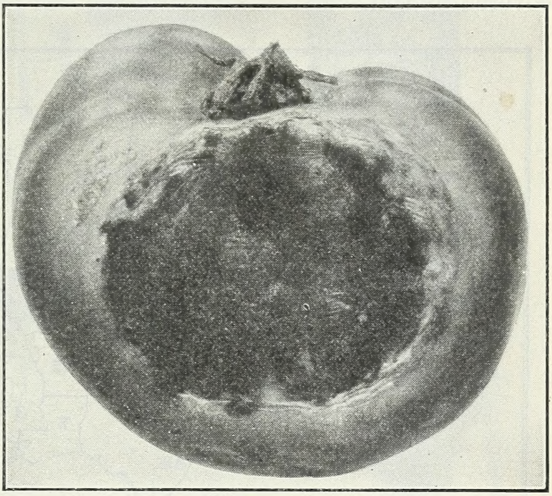


FIG. 2.—A stage of sun scald later than that seen in Figure 1, showing the typical appearance of such spots after a black mold (*Alternaria* sp.) has grown on the surface

TABLE 1.—*Overwintering of tomato leaf-spot fungus on dead weeds, grasses, and crop remains*

Sterilized materials used as culture media	Condition of cultures when set outdoors		Condition of cultures the following spring and summer
	Age (days)	Growth	
Cotton and sweet-clover stems (tubes plugged with cotton).	21	----------	Pycnidia and spores abundant.
Cotton and sweet-clover stems (tubes closed with sealing wax).	21	----------	Do.
Crabgrass	18	Sparse	Pycnidia and spores fairly abundant.
Mixed field grasses	18	Fair	Do.
Cornstalks	18	Abundant	Pycnidia and spores very abundant.
Ambrosia artemisiaefolia	18	Fair	Pycnidia and spores present.
Amaranthus retroflexus	18	None	No pycnidia or spores.
Chenopodium alba	18	do	No growth.
Eleusine indica	18	Fair	Pycnidia and spores fairly abundant.

It is evident from the results presented in Table 1 that the tomato leaf-spot fungus is able to grow and sporulate on a number of dead weed and crop plants. Its abundant sporulation on cornstalks agrees with its behavior on corn meal and corn-meal agar, on which, with the possible exception of potato agar, it fruits better in pure culture than on any other medium used. It would be interesting to know whether it also grows and fruits abundantly on dead potato vines. Apparently this fungus will not grow on rough pigweed and lambs-quarters. In fact, none of the tomato parasites tried grew on lambs-quarters. From the results of these experiments it would appear that the fungus can live from year to year on dead cornstalks, weeds, and pieces of crop plants not completely covered by soil.

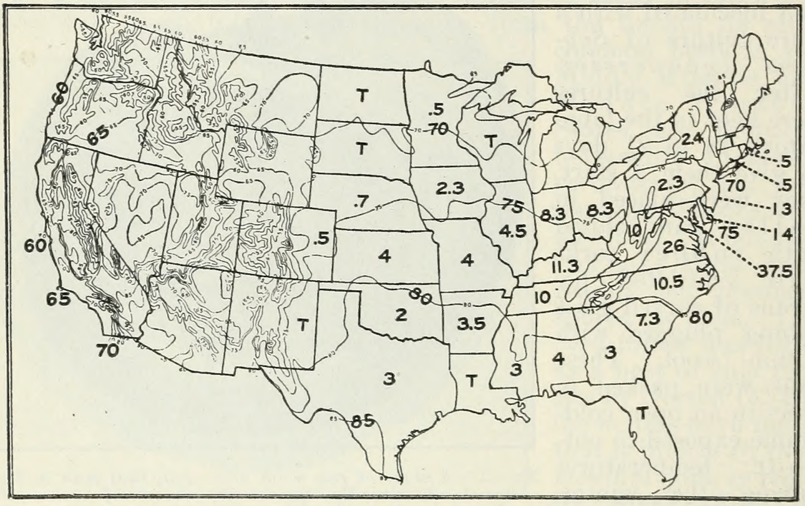
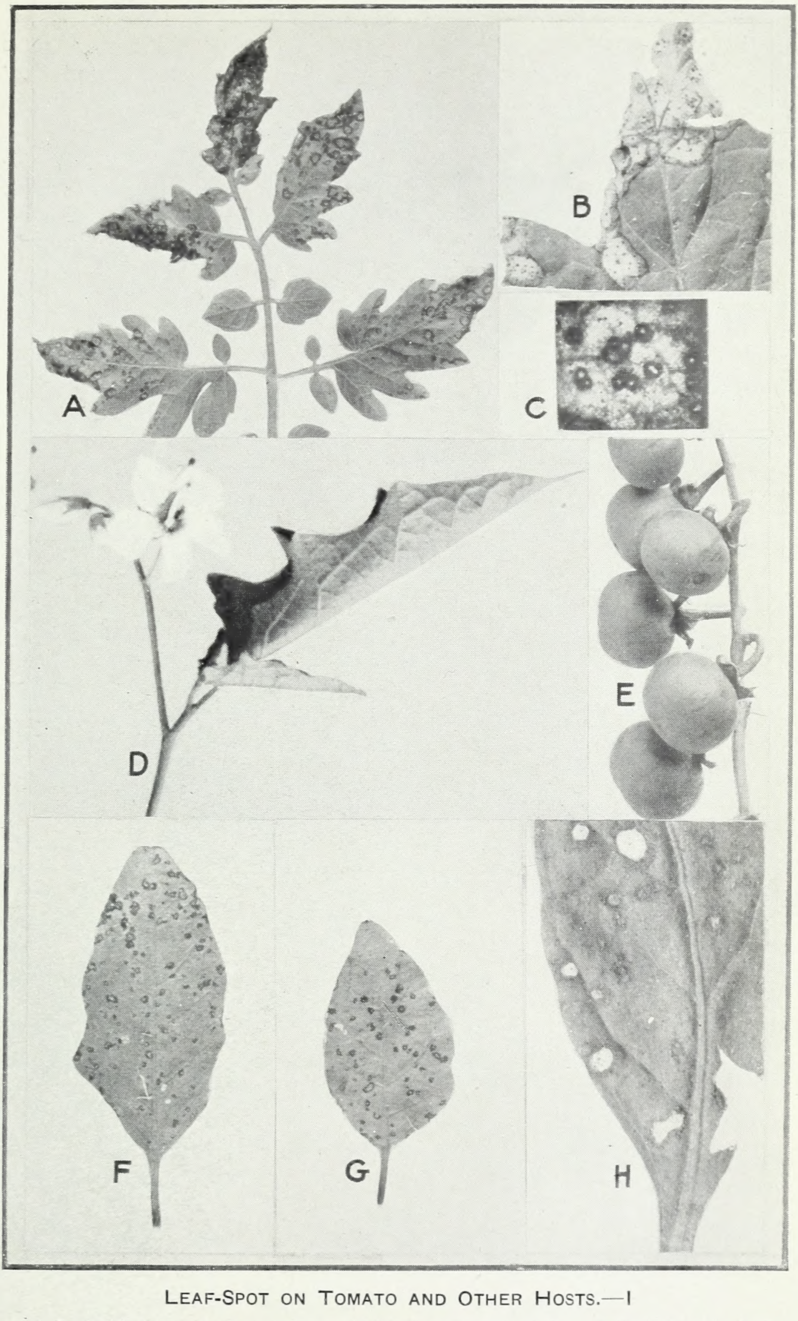


FIG. 3.—Outline map of the United States, showing the relation of temperature to the distribution of tomato leaf-spot. The isotherms and temperature figures indicate the average monthly temperature for July; other figures show the average percentages of tomato crops destroyed by leaf-spot from 1918 to 1921

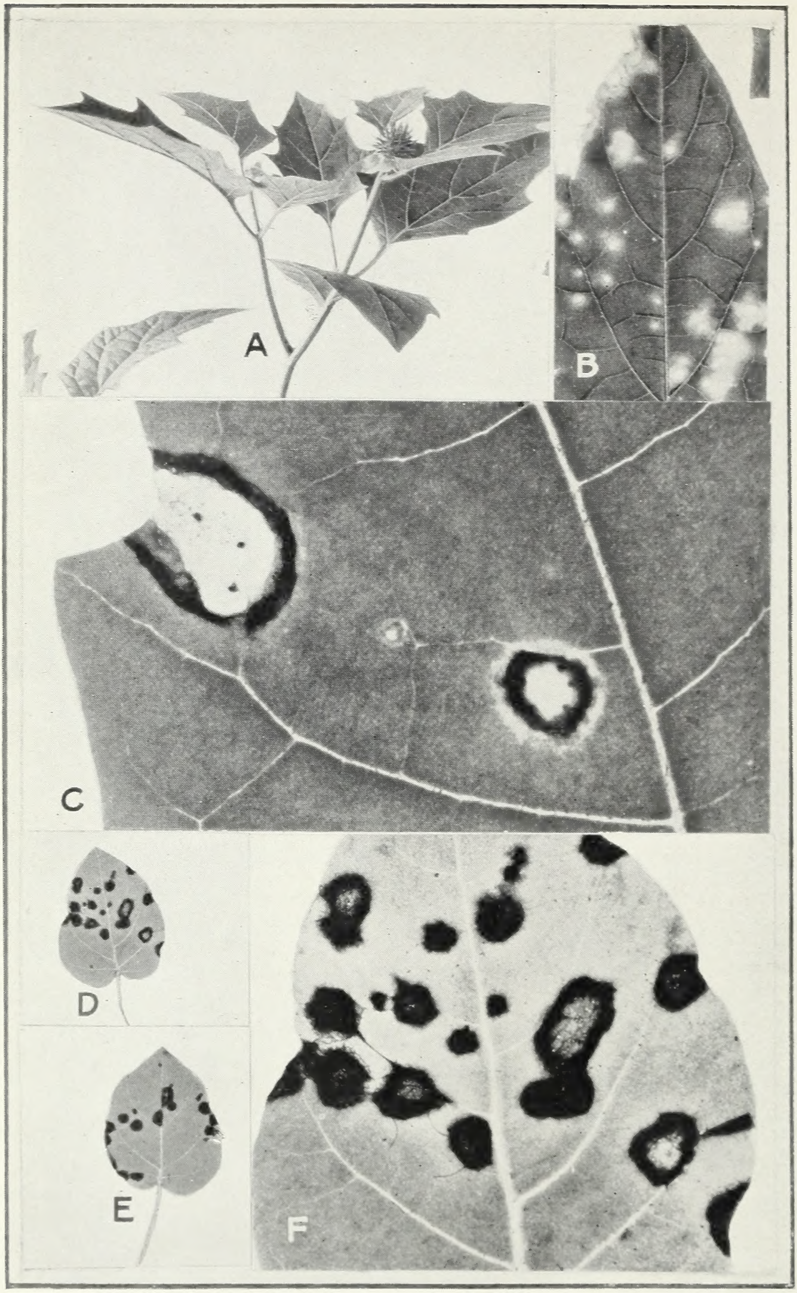
EFFECT OF SOIL ON THE VIABILITY OF THE FUNGUS

As weeds and crop remains are largely covered by soil in plowing and most fungi do not grow in soil, experiments were made to determine the effect of soil on the viability of the leaf-spot fungus. Dead plant material was tubed and sterilized, as in the previous experiments, inoculated with *Septoria lycopersici*, and after 3 to 18 days thoroughly covered with soil. The tubes were then plugged with cotton wool, packed in cans, and exposed during the winter to outdoor temperatures. Those kept in the laboratory 3 days were not examined before the addition of soil, as Septoria grows very slowly and the period was too short for visible growth on most of this material. As the same kinds of media and the same tubes of inoculation material were used in both the 3-day and 18-day sets and growth was evident in the latter, it no doubt had started in the former before the addition of the soil. The effects of the soil on the viability of the fungus, as determined by microscopic examina-



LEAF-SPOT ON TOMATO AND OTHER HOSTS.—I

A, Leaf-spot of tomato (*Septoria lycopersici* Speg.); spots natural size. *B*, Part of tomato leaf enlarged to show pycnidia, or spore pustules (small black bodies), on light-gray spots. *C*, A single spot of the leaf shown in *B* considerably enlarged; ostioles appear as small white openings in center of pycnidia. *D*, Flower and leaf of horsenettle (*Solanum carolinense*). *E*, Seed balls of horsenettle. *F* and *G*, Leaf-spot of horsenettle produced by inoculation with a pure culture of *Septoria lycopersici* from tomato. *H*, Part of horsenettle leaf enlarged to show pycnidia of *Septoria lycopersici*



LEAF-SPOT ON TOMATO AND OTHER HOSTS.—II

A, Jimsonweed (*Datura stramonium*) *B*, Leaf-spot of jimsonweed produced by inoculation with a pure culture of *Septoria lycopersici* from tomato. *C*, Two spots shown in *B* enlarged to show pycnidia, or spore pustules, of *Septoria lycopersici*. *D* and *E*, Leaf-spot of *Solanum floridanum* produced by inoculation with a pure culture of *Septoria lycopersici* from tomato. *F*, Spots shown in *D* enlarged to show pycnidia of *Septoria lycopersici*. Only the white ostioles are visible, as the pycnidia are embedded in the leaf tions, plate cultures, and inoculations of tomato plants with aqueous extract from the soil, are shown in Table 2.

TABLE 2.—*Results from adding soil to cultures of the tomato leaf-spot fungus exposed during winter*

Culture medium (sterilized)	Condition of culture before the addition of soil and its exposure to winter temperature		Kind of soil added to culture	Condition of culture the following spring and summer
	Age (days)	Growth		
Crabgrass	3	Not examined	Sterilized	No growth.
Mixed field grasses	3	do	do	No viable Septoria.
Cornstalks	3	do	do	Pycnidia and spores present.[1]
Ambrosia artemisiaefolia	3	do	do	No pycnidia or spores.
Amaranthus retroflexus	3	do	do	Do.
Chenopodium alba	3	do	do	Do.
Eleusine indica	3	do	do	No growth.
Crabgrass	3	do	Unsterilized	No Septoria present.
Mixed field grasses	3	do	do	Do.
Cornstalks	3	do	do	Do.
Ambrosia artemisiaefolia	3	do	do	Do.
Amaranthus retroflexus	3	do	do	Do.
Chenopodium alba	3	do	do	Do.
Eleusine indica	3	do	do	Do.
Crabgrass	18	Fair	Sterilized	No viable Septoria.
Mixed field grasses	18	do	do	Do.
Cornstalks	18	Abundant	do	Do.
Ambrosia artemisiaefolia	18	Fair	do	Do.
Amaranthus retroflexus	18	None	do	No growth.
Chenopodium alba	18	do	do	Do.
Eleusine indica	18	Fair	do	No viable Septoria.
Crabgrass	18	do	Unsterilized	Do.
Mixed field grasses	18	do	do	Do.
Cornstalks	18	Abundant	do	Do.
Ambrosia artemisiaefolia	18	Fair	do	Do.
Amaranthus retroflexus	18	None	do	No growth.
Chenopodium alba	18	do	do	Do.
Eleusine indica	18	Fair	do	No viable Septoria.

[1] These pieces of cornstalk were rather thick and large in proportion to the quantity of soil used. No growth was obtained when a much larger proportion of soil was used.

The addition of soil to the cultures destroyed the viability of *Septoria lycopersici* during the winter, except in some tubes containing cornstalks. As the pieces of cornstalk were rather thick the fungus may not have obtained the full effect of the soil in these tubes. In the presence of unsterilized soil in the 3-day set and of both sterilized and unsterilized soil in the 18-day set, Septoria cultured on cornstalks lost its viability during the winter. Similar results were obtained on all the other media covered with soil and exposed to the same temperatures.

CONTROL MEASURES

USE OF EARLY PLANTS

As previously stated, the tomato leaf-spot fungus not only has a narrow range of sporulation temperatures, viz, 59° to 80.5° F., but requires a month at 59° to produce spores. Because of these temperature limitations it is greatly retarded in its development and does not usually appear on plants in the field in the Middle Atlantic and Middle Western States before the middle or latter part of June. Consequently the use of very early plants offers a means of escaping much of this disease. Moreover, an earlier crop would have more favorable temperature conditions for the production of fruit, as the average temperature during the growing season in this region is somewhat above the optimum.

Plants of suitable size and age for an early crop, if produced locally, would have to be grown in hotbeds and coldframes instead of in open beds. This would necessitate some additional expense, but it would soon be repaid by the increased returns.

Southern-grown early tomato plants have been used to some extent by northern tomato growers during the past eight years; in fact, more than 30,000,000 of these southern-grown plants were shipped into Indiana in 1923. Some of the largest northern companies manufacturing tomato products are establishing plant-growing connections in the South as a means of providing or enlarging their supply of early plants. These companies furnish their own seed and either grow the plants themselves or have them grown under the supervision of their men. Special effort is made to produce large, stocky, healthy, well-grown plants which are at least 6 weeks old at the time of shipment.

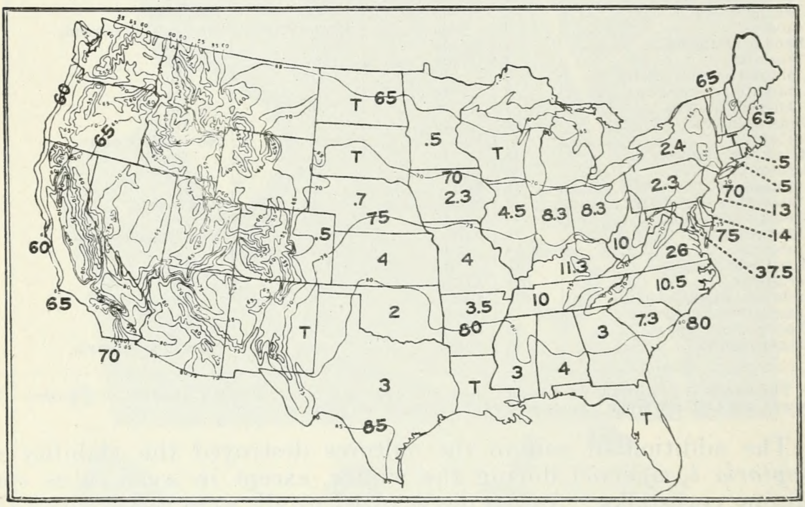


FIG. 4.—Outline map of the United States, showing the relation of temperature to the distribution of tomato leaf-spot. The isotherms and temperature figures indicate the average monthly temperature for August; other figures show the average percentages of tomato crops destroyed by leaf-spot from 1918 to 1921

Early plants produced in the South for planting in the North should be grown under good culture and from high-grade seed. They should be reasonably well hardened to withstand shipment, but their growth should not be appreciably checked nor their stems allowed to become tough and woody. Sowing the seed rather thinly, so that the plants will have plenty of room, and using a fertilizer containing a liberal proportion of potash and a small quantity of nitrogen will aid materially in producing uniform well-grown plants. A slow steady growth without serious check is essential. Where the plant beds are irrigated the water may be withheld for a few days prior to shipping. Much depends upon lifting the plants carefully in order to retain the largest possible portion of their root system. Careful packing for shipment will also aid materially in getting the plants to their destination in good condition. The weather, which also has a marked effect on type of growth, is, however, always an uncertain factor.

One of the greatest objections to the use of southern-grown tomato plants is the danger of introducing serious diseases. This has already happened in Indiana. For the past eight years the tomato-wilt fungus has been carried into the fields of this State through the use of large numbers of uninspected southern-grown tomato plants. These small infestation spots will gradually spread until they become a serious factor in tomato production. Root-knot is another disease often carried on tomato seedlings shipped from the South. In 1923 the State entomologist of Indiana found nematodes (the cause of root-knot) on some southern-grown tomato plants and tried to inspect all subsequent shipments coming into the State. During the remainder of the season he condemned approximately 2,385 cases of tomato plants on account of root-knot. Some of these showed only a scattered infestation throughout the crates, but others were severely affected. The shipment of infected seedlings even for this one year would have been sufficient to cause a widespread distribution of the root-knot nematode in the State if the plants had not been condemned and destroyed. There are several other fruit and stem parasites of the tomato that may be carried into northern fields in the same manner.

The production of southern-grown plants by the companies using them is a safer practice than to buy them in the open market. Without some such direct connection between user and grower that will insure a supply of plants of the proper age, size, variety, and condition, the use of southern-grown plants in the North is attended with much danger.

Owing to the danger of introducing serious tomato diseases, the use of southern-grown tomato plants can be recommended only when they are properly grown on clean land and when every possible precaution is taken to keep them free from disease. The plants should be grown from high-grade seed of the varieties and strains best adapted to the conditions and uses of the locality in which the crop is to be grown. The plants themselves should be large, stocky, well rooted, and fairly well hardened at the time of shipment. In lifting the plants care should be taken to retain their roots, and they should be so packed that they will carry to destination in good condition. With these assurances and precautions, great possibilities are doubtless afforded by the use of southern-grown tomato plants. The northern tomato grower, however, may gain little financially or otherwise from the use of these plants as compared with those grown locally in hotbeds and coldframes.

PREVENTION OF OVERWINTERING

The marked effect of soil on the overwintering of Septoria suggests the possibility of preventing leaf-spot epidemics by thoroughly plowing under all dead tomato vines and other Septoria-infested material in the fall to prevent the fungus from living over winter. Some field experiments were made to test the effect of this practice. Four isolated plats which lay at some distance from other tomato fields and which had never been cropped with tomatoes or at least not for many years were selected for this purpose. Two of these were on high land and two on low parts of the farm. On one high and one low plat tomato stems and leaves infected by Septoria were distributed in the bottom of the furrow as the land was plowed in the fall; on the others they were scattered on the surface. No further treatment was given until spring, when all plats were disked and planted with tomatoes. Cultivation was delayed until the plats became weedy, in order to prevent bringing in spores from other fields. The results noted on July 11 are recorded in Table 3.

TABLE 3.—*Results of experiments to control tomato leaf-spot by thoroughly plowing under the dead tomato vines in the fall*

[Infected tomato stems and leaves distributed in the fall; land disked in the spring; examination of results on July 11]

Character of the plats	Plowed plats: Infected material distributed in the bottom of the furrow			Control plats: Infected material distributed on the surface		
	Total number of plants	Number of plants infected	Plants infected (per cent)	Total number of plants	Number of plants infected	Plants infected (per cent)
High land	75	0	0	97	86	88.6
Low land	77	0	0	99	23	[1] 23.2

[1] Water flowed over this plat in the spring and deposited a layer of mud which covered most of the old tomato stems and leaves.

On July 11 no tomato plants were infected on the plowed plats, but 88.6 and 23.2 per cent were infected on the controls. A layer of mud deposited in the spring on the control which contained 23.2 per cent of infected plants apparently reduced the proportion of Septoria. Late in the season there was a little infection by Septoria on the plowed plats, but this was after they had been cultivated several times and the fungus had apparently been carried in by men and teams, or possibly by insects from other tomato fields. However, the amount of Septoria on these plats even at the end of the season was relatively small. These results agree with those obtained by the use of soil in tube cultures and seem to indicate that Septoria may be largely prevented from overwintering by thoroughly plowing under the dead tomato vines in the fall. Even if the plowing were delayed until early spring it might possibly be made effective by thoroughly turning under all the tomato vines, harrowing the surface lightly, and planting the land to a noncultivated crop. Planting all tomatoes on fall-plowed land would also help control leaf-spot, or blight, as the fall plowing would destroy the leaf-spot fungus that would otherwise live over winter in these fields on crop débris, horsenettle, jimsonweed, goundcherry, and black nightshade.

Ordinary plowing will not thoroughly cover the vines. Vines only partly covered are even more favorable for the development of Septoria than those lying on the surface, for the covered parts act somewhat as roots by keeping the exposed parts moist. The work of covering the vines can be facilitated by cutting them with a disk and plowing them under with the aid of a weedhook or a weedhook and jointer. The disk should not bury the vines very deeply, however, or they will be brought to the surface again by the plow.

If pieces of the vines are left on the surface or so near the surface that they will soon become exposed, they will be likely to carry the disease over winter. Hence disking and plowing will not suffice unless the vines are completely covered.

The practice of disking tomato land and sowing it to wheat or rye and grass in the fall enables the tomato leaf-spot fungus to live over winter on pieces of dead tomato vines. Soon after the grain is cut it can pass to the dead stubble[3] and live over another winter. By the time the stubble is exhausted it will have plenty of dead grass leaves to subsist upon. Hence the fungus can live from year to year as a saprophyte under this system, as it has plenty of dead organic matter as food. Unless the tomato vines bearing the fungus are thoroughly covered by soil, this parasite will apparently continue to flourish in tomato regions of the Middle Atlantic and Middle Western States.

The control of tomato leaf-spot by preventing the multiplication of the fungus rather than the infection of the plants is wholly a matter of field sanitation. Moreover, it requires no chemicals, no extra men, teams, or time, but merely a careful execution of a customary field operation. Its effect will depend on how thoroughly it is done and how commonly it is practiced.

DESTRUCTION OF OTHER HOSTS

The tomato leaf-spot fungus is capable of living on a considerable number of hosts. In addition to the common garden tomato Norton (*5*) succeeded in infecting eggplant (*Solanum melongena*), purple thorn apple (*Datura tatula*), potato (*Solanum tuberosum*), currant tomato (*Lycopersicum pimpinellifolium*), and horsenettle (*Solanum carolinense*). Beach (*1*) added to this list prairie groundcherry (*Physalis lanceolata*), clammy groundcherry (*Physalis heterophylla*), black nightshade (*Solanum nigrum*), and petunia. The writers (*9*) found that the fungus is not only capable of infecting horsenettle (Pl. I, *D* to *H*) but actually infects it as commonly as the tomato and also sporulates on it. Eggplant (fig. 5) is also quite as susceptible as horsenettle. Potatoes (fig. 6) in our experiments were less susceptible than horsenettle or eggplant, but most of our experiments were made with Irish Cobbler, which may be more resistant than some other varieties. We have also found that the leaf-spot fungus infects *Cyphomandra betacea* (tree-tomato), *Solanum floridanum* (Pl. II, *D* to *F*), *Solanum mammosum*, and *Datura stramonium* (Pl. II, *A* to *C*). Quite likely it infects a number of other hosts.

Aside from the tomato the only known hosts of this fungus commonly found in the fields of the Middle Atlantic and Middle Western States are jimsonweed, purple thorn apple, horsenettle, potato, black nightshade, prairie groundcherry, clammy groundcherry, and eggplant. The tomato, potato, and eggplant crops should be thoroughly plowed under at the end of the growing season, and the other hosts should be kept out of the fields and waste places, such as fence rows and roadsides.

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[3] *Septoria lycopersici* grows slowly but fruits abundantly on wheat straw.

USE OF CLEAN SEED BEDS

Tomato leaf-spot is often found in the seed beds in Maryland and doubtless occurs at times in such beds in other States. As the seed bed is usually made on a well-manured piece of land and located in a protected place, it is warmer than in the open field. The fungus is therefore able to grow and develop spores much earlier than in exposed places. In sheltered open coldframes facing the sun the writers have obtained pycnidia and spores of *Septoria lycopersici* on dead tomato stems as early as May 24 at Washington, D. C. The fungus is carried on the plants from the seed bed to the field, where it spreads and produces an epidemic much earlier than it otherwise would. Much heavier losses therefore result from its early development.

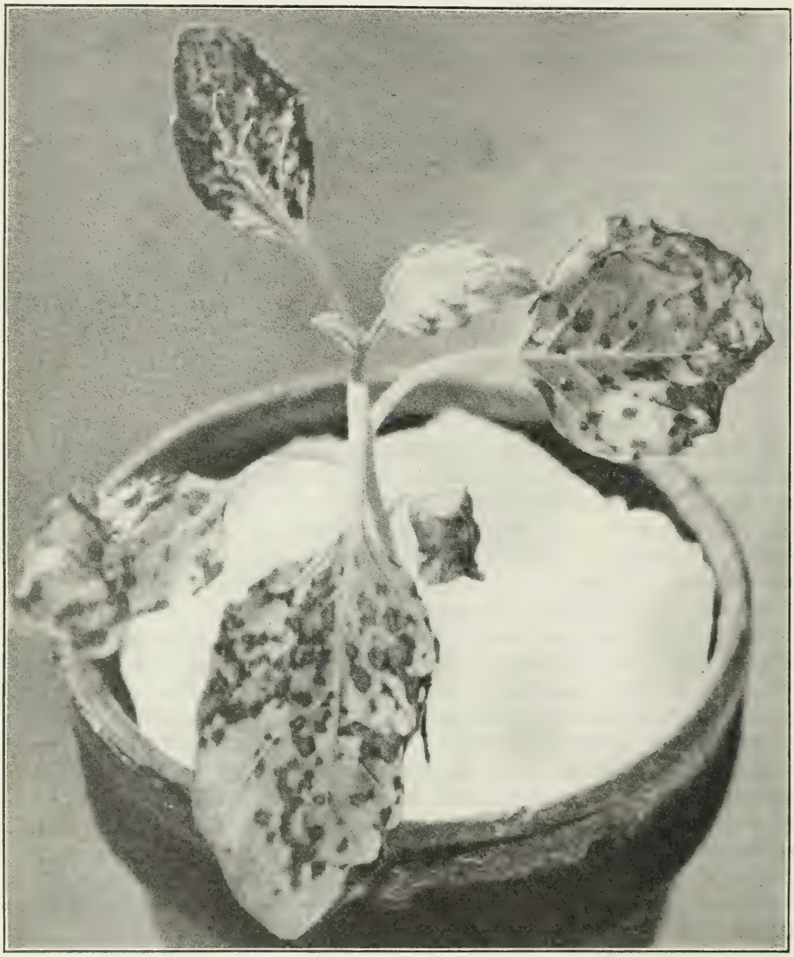

FIG. 5.—Eggplant infected by *Septoria lycopersici*

Tomato plants from a seed bed infested with Septoria should not be used. The cost of healthy plants is little in comparison with the extra loss that would result from the use of diseased seedlings.

If the seed bed is infested by Septoria, it should be sterilized or abandoned. Full directions for sterilizing seed beds are published in Farmers' Bulletin 996 (*2*), a copy of which may be obtained by writing to the Department of Agriculture, Washington, D. C.

The development of Septoria and the infection of tomato seedlings with leaf-spot can often be prevented in the seed bed by immersing the seed for five minutes in a solution consisting of 1 part of bichloride of mercury to 3,000 parts of water and washing it for 10 minutes in running water and by spraying the plants two or three times with Bordeaux mixture before they are set in the field.

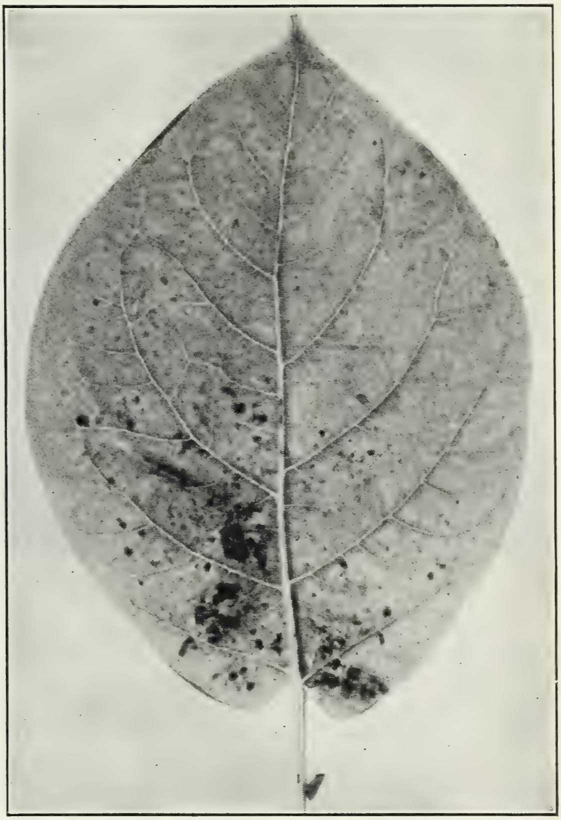

FIG. 6.—Potato leaf infected by *Septoria lycopersici*

ROTATION OF CROPS

Growing any crop continuously or even frequently on the same piece of land usually results in an accumulation of its diseases. Rotation of crops, however, hinders their development, for the parasites which infect one crop seldom are able to attack another. When a parasite can grow and sporulate on several different species of plants, all of these hosts have to be kept off the land for several years or the rotation will have little effect. Even if tomatoes are grown on the same piece of land only once in five years, the leaf-spot fungus will be ready to attack the next tomato crop in full force if horsenettle, jimsonweed, or other hosts are allowed to flourish there.

Since this fungus can grow and sporulate on dead cornstalks, the use of corn in rotation with tomatoes has certain disadvantages. If the cornstalks remaining on the field are not thoroughly plowed under at the end of the season, they may become infected by the fungus, especially if tomatoes, horsenettles, or jimsonweeds are growing in adjoining fields. This would result in its rapid multiplication. The effect of growing tomatoes after corn in this case is obvious. It is doubtful, therefore, whether corn should ever immediately precede tomatoes in an area heavily infested with leaf-spot.

USE OF MANURE AND FERTILIZERS

A liberal use of commercial fertilizers, barnyard manure, or green manure is essential on most soils to produce a profitable crop. In fact, the best yields of tomatoes in the East and South are usually obtained by growers who keep their soil in a fairly high state of fertility by the use of liberal quantities of organic matter and commercial fertilizers.

Fertilizers, if properly balanced and judiciously used, do not induce susceptibility to leaf-spot (*11*). Plants growing very rapidly, however, are more susceptible than those growing slowly. An excess of nitrogen or a very heavy application of mixed fertilizer in a wet season or on low wet land may cause excessive vine growth, especially in late varieties, and this usually induces increased susceptibility to leaf-spot. Moreover, heavy vine growth generally results in the production of very little pollen and consequently a poor set of fruit. Where a poor set is common it would probably be advisable to withhold part of the nitrogen until the fruit begins to set. More can then be applied with safety, as the growth of the fruit checks the growth of the vine.

The chief use of fertilizer is to produce fruit. A certain growth of vine is necessary for high yields, but an excess retards fruiting and not infrequently reduces the yield. Fruiting should start early and continue during the season normal for the variety, as the quantity of fruit a vine can produce at one time is limited. The moderate proportion of foliage usually accompanying high yields of fruit dries off quickly after rains and therefore offers less opportunity than heavy dense vines for the development of leaf-spot.

SPRAYING AND DUSTING

Tomato leaf-spot can be controlled to a considerable extent by repeatedly spraying[4] (fig. 7) or dusting the plants with fungicides. Of these two processes, spraying has usually given the better results. The increase that can be obtained from spraying tomatoes differs somewhat, however, because of differences in the fertility of the soil and variations in the severity and duration of the disease. On a soil capable of producing high yields spraying is commonly profitable if the disease is severe, but on poor land it often gives little, if any, increase over the expense. In the latter case it would be more profitable to spend the money for extra fertilizer. Moreover, if the disease is only of moderate severity or if its development is delayed until the crop is nearly mature, it may not do enough damage to make spraying profitable. Profits from spraying are also affected by prices of tomato fruit. An increased yield may be profitable when the price of the fruit is high and unprofitable when it is low.

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[4] Either 4–4–50 Bordeaux mixture (4 pounds copper-sulphate crystals, 4 pounds stone lime, and 50 gallons water) or 4–2–50 Bordeaux mixture (4 pounds copper-sulphate crystals, 2 pounds stone lime, and 50 gallons water) usually gives fairly good control of the disease if thoroughly applied at proper intervals. The effectiveness of these spray mixtures is improved, however, by the addition of 2 or 3 pounds of rosin-fishoil soap to each 50 gallons. Before the soap is added it should be dissolved in a small quantity of hot water.

Successful spray methods for the control of tomato leaf-spot were worked out in 1897 and 1898 by M. B. Waite, who had identified this species of Septoria on the tomato on his farm in Anne Arundel County, Md., in 1896. His methods consisted of spraying the seed bed two or three times after the plants began to form rough leaves and spraying the crop about three times after the plants had begun to form foliage rapidly. This was on late tomatoes, which not infrequently become heavily infected in the seed bed.[5]

The heavy leaf-spot epidemics occurring on tomatoes grown for the canneries nowadays are difficult to control with fewer than five field applications of spray mixture, especially when they are started fairly early; and under these circumstances the later applications are more effective than those applied in the early part of the season. Moreover, 100 gallons of 4–4–50 Bordeaux mixture per acre at each application are more effective than 50 gallons, the quantity usually applied. The effectiveness of Bordeaux mixture is still further improved by adding to each 50 gallons of spray liquid 2 or 3 pounds of rosin-fishoil soap, which facilitates spreading. The soap should be dissolved in a small quantity of hot water before it is added to the mixture.

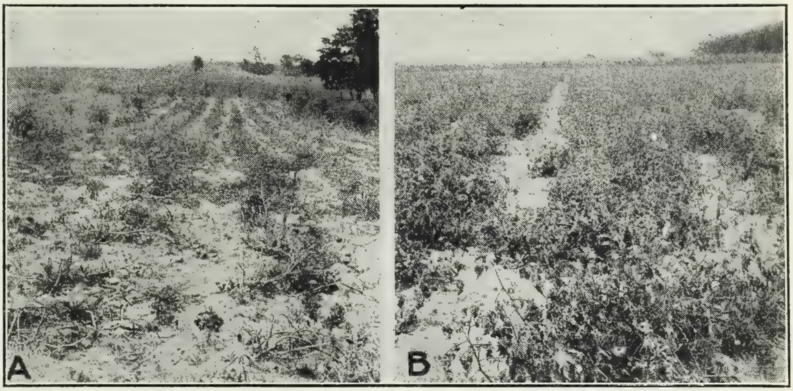

FIG. 7.—Two adjoining fields of tomatoes on the same farm: *A*, Unsprayed; plants defoliated by leaf-spot: *B*, sprayed; plants healthy

The increased yields obtained by spraying tomatoes from 1916 to 1918 in the Middle Atlantic and Middle Western States by the United States Department of Agriculture (*8*), State experiment stations, and certain large manufacturers of tomato products, working cooperatively, are summarized in Table 4. They represent about the average increases that may be expected from spraying tomatoes in this region.

In these experiments spraying increased the yield from 6.9 to 47 per cent. The increase of 6.9 per cent was obtained in a field in which leaf-spot did not appear until near the end of the picking season. Consequently there was little injury and little gain. Although the results were variable, the average increase in the other fields was about 30 per cent. From these experiments it would seem that thorough spraying in this region would usually increase the yield from 20 to 25 per cent.

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[5] Oral statement to the writers.

TABLE 4.—*Effect of spraying on the yields of tomatoes*

[The spray mixtures used at each locality named were 4-4-50 Bordeaux mixture (4 pounds copper-sulphate crystals, 4 pounds stone lime, and 50 gallons water), 4-2-3-50 Bordeaux soap (4 pounds copper-sulphate crystals, 2 pounds stone lime, 3 pounds rosin-fishoil soap, and 50 gallons water), and 0.5-0-3-50 copper soap (one-half pound copper-sulphate crystals, no lime, 3 pounds rosin-fishoil soap, and 50 gallons water). As these spray mixtures were about equally effective, the results of all the sprayed plats are summarized in one group.]

Locality	Year	Number of plats		Number of applications	Yield per acre of ripe fruit (pounds)		Increased yield from spraying	
		Sprayed	Controls		Sprayed	Controls	Pounds	Per cent
Salem, N. J	1916	21	12	4	9,120	6,200	2,920	47
Riverton, N. J	1917	20	4	7	13,629	11,529	2,100	18.2
Hurlock, Md	1917	31	8	4	6,233	5,343	880	16.5
Salem, Va	1918	10	4	3	3,519	2,750	769	28
Paoli, Ind	1918	11	5	3	14,610	12,487	2,123	17
Riverton, N. J	1918	12	5	7	10,276	9,610	666	6.9
Hurlock, Md	1918	6	3	5	11,533	8,967	2,566	28.6

Spraying in areas heavily infested with leaf-spot not only increases the yield but also improves the quality of the fruit. Defoliation by leaf-spot deprives the plant of its power to grow and develop its fruit, for it is in the leaves that it converts the carbon dioxide, water, and minerals obtained from the air and soil into foods. The new leaves produced at the tips of the branches make some food, but not enough. Consequently the fruit of such plants is small, watery, and deficient in flavor and solids, especially carbohydrates. It is also predominantly yellow instead of scarlet, for the direct rays of the sun are too hot for the development of lycopin, the red pigment, but favorable for the development of the yellow pigment (*3* and *4*) carotin; hence leaf-spot causes considerable loss in quality as well as in yield of fruit, but this loss may be largely prevented by spraying. Full directions for spraying tomatoes for the control of leaf-spot have been published in Circular No. 4 of the Office of Cotton, Truck, and Forage Crop Disease Investigations, Bureau of Plant Industry (*7*).

Dusting has some advantages over spraying, but it is not usually so effective for the control of tomato leaf-spot. The relative cost of the equipment and the ease of application are greatly in its favor. A small hand duster (fig. 8) is fairly satisfactory for a small tomato acreage, as with it one man can do the work and often at a time when it would be difficult to go into the field with a spray machine. It is therefore easier to make the applications at proper intervals. For larger acreages power dusters are essential.

The present limitations of dusts are due largely to their less effective covering and sticking qualities and consequent poorer control of diseases. A dust should form a uniform film, or coating, on the foliage, adhere well, and prevent parasites from infecting the plant through the dusted parts. It should also possess such chemical and physical properties that it will continuously renew the coating where the film is broken by the growth or enlargement of the leaves. Moreover, it should withstand weathering. Dry Bordeaux mixture made with an excess of lime forms a rather uniform coating on the foliage and renews the films but does not adhere well. Copper-soap dusts[6] adhere much better than Bordeaux dust and protect the covered parts from the action of parasites but do not renew the films well. Experiments now being conducted with different proportions of dry Bordeaux and copper-soap dusts may lead to the development of a more effective dust fungicide than either dry Bordeaux or copper-soap dust, but it is quite evident that much study of the fundamentals of both spraying and dusting is necessary to put this work on a highly effective basis.

Although dusting has not given as good results on the average as liquid spray mixtures, it may ultimately replace spraying; in fact, dusting is now successful with some crops, and experiments with copper-soap dusts (*10*) on tomatoes seem promising.

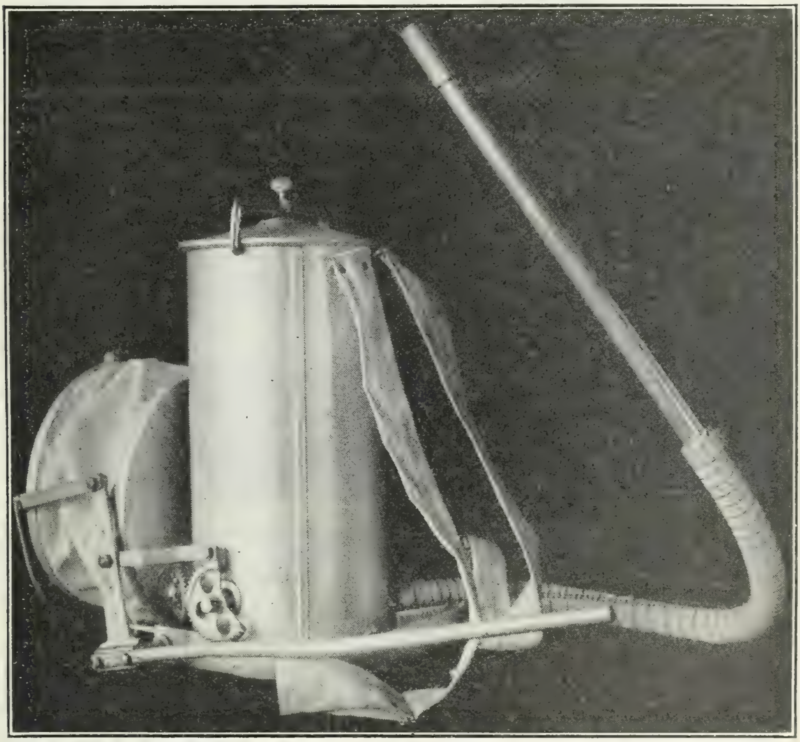

FIG. 8.—A good bellows-type hand duster. Several good crank and fan types are also on the market

DEVELOPMENT OF RESISTANT VARIETIES

The development of first-class blight-resistant varieties of tomatoes would give the best solution of the tomato leaf-spot problem. Unfortunately, all the domestic and foreign cultivated varieties which it has been possible to get from seedsmen and the numerous wild varieties obtained through the Office of Foreign Seed and Plant Introduction have shown about the same degree of susceptibility to this disease. In fact, the most resistant varieties seen are those developed by the United States Department of Agriculture for resistance to wilt (*6*)[7] and hybrids from them (fig. 9). Although these varieties possess a little resistance to leaf-spot and have transmitted an intensification of this quality to some of their hybrids, neither they nor their hybrids are resistant enough to fully meet commercial needs. Further crossing and selection may lead to greater improvement, but the most hopeful possibility lies in the introduction of a resistant wild form that possesses desirable fruit and vine qualities for crossing. At present no varieties are known more resistant than the Marvel, Norton, and Norduke and some of their unnamed hybrids.

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[6] These dusts are made from copper sulphate and salts of stearic and other high-melting fatty acids and contain from 4 to 8 per cent of metallic copper.

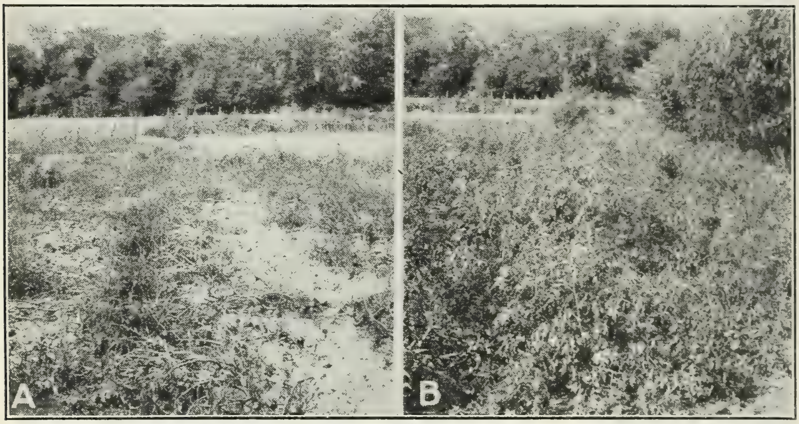

FIG. 9.—Comparative resistance to leaf-spot of tomato varieties growing in the same experimental plat: *A*, Commercial varieties defoliated by *Septoria lycopersici*; *B*, the Marvelosa variety, developed from a cross between Marvel and Ponderosa. This is a promising new pink-fruited variety showing partial resistance to leaf-spot

SUMMARY

Tomato leaf-spot, or blight, causes an average annual loss of approximately 250,000 tons of commercial tomatoes in the United States.

The use of Bordeaux or other copper-spray mixtures has given the most effective control of leaf-spot in the past, but the profits from spraying are variable and not always sufficient to justify the expense. A more effective and economical method of control lies in the use of modified field practices.

The effects of tomato leaf-spot epidemics can be largely avoided by setting out large, stocky, well-hardened plants early in the spring. As the leaf-spot fungus has a high minimum sporulation temperature, viz, 59° F., and therefore seldom infects tomato plants in the field in the Middle Atlantic and Middle Western States, the region where it is severe, before June 15 to 30, these early plants escape more leaf-spot than the small plants commonly set late.

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[7] Pritchard, F. J., and Porte, W. S. History and description of the Norduke wilt-resistant tomato. (Manuscript.)

Large stocky plants at least 6 weeks old can be produced cheaply outdoors in the South and shipped north at any convenient date for planting. More than 30,000,000 southern-grown tomato plants were shipped into Indiana and a considerable number into Eastern States in 1923. Some of the larger northern companies manufacturing tomato products grow their own plants in the South. Although the use of southern-grown plants in the North has increased rapidly in the past seven years, it has distributed wilt and root-knot in many clean fields. The need of a system of plant certification is therefore apparent.

The overwintering of the leaf-spot fungus can be largely prevented by plowing under the old tomato vines in the autumn. This fungus overwinters chiefly on the old vines but can not live until spring in the soil. Plowing under the vines in the fall therefore kills it. Good results have been obtained by this method in field experiments. The vines have to be thoroughly covered, however, to kill all the fungus on them, but this can be done by cutting them with a disk and plowing them under with the aid of a weedhook or a weedhook and jointer.

The common practice of disking instead of plowing under the old tomato vines in the fall is doubtless largely responsible for leaf-spot epidemics in the United States. The parts of the old vines left lying on the surface of the soil furnish excellent material for the overwintering and saprophytic development of the fungus.

The tomato leaf-spot fungus also grows and produces spores on dead weeds, grasses, and the remains of various crops, especially cornstalks. Keeping these dead materials covered with soil by plowing or cultivating robs the fungus of this food supply and increases its difficulty of living from year to year as a saprophyte.

The destruction of horsenettle, groundcherry, jimsonweed, and nightshade, on which the leaf-spot fungus lives as a parasite, the burning of dead weeds and grasses along fence rows and in other waste places, and the practice of clean culture generally will aid in the control of this disease.

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